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COMMENTS ON 'POSSIBLE ROLE OF MHD WAVES IN HEATING THE SOLAR CORONA' BY DWIVEDI AND PANDEY

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Abstract. We comment on the recent paper by Dwivedi and Pandey (*Solar Physics*, **216**, 59, 2003). Parts of that paper closely reproduce, without reference, material that we had published previously, while other parts deviate from our earlier analysis contain several critical flaws. We show that magnetoacoustic waves are capable of heating the corona with a modest enhancement in the coefficient of compressive viscosity.

Observations of rapidly damped transverse loop oscillations by the Transition Region and Coronal Explorer (TRACE) suggest that the coefficient of shear viscosity in the corona may be eight orders of magnitude larger than the value given by classical transport theory (Nakariakov *et al.*, 1999). This led Dwivedi and Pandey (2003, henceforth DP) to consider the consequences of this enhancement for the heating of the corona by magnetoacoustic waves. This is a worthy goal, but their paper unfortunately suffers from several critical flaws.

The paper begins with a derivation of a general dispersion relation for linear waves propagating in a uniform medium subject to damping by *compressive* viscosity and thermal conduction. Such a dispersion relation was derived previously by Porter, Klimchuk, and Sturrock (1994, henceforth PKS). DP claim that the energy equation used by PKS is incorrect and that the resulting dispersion relation and solutions are therefore in error. However, it is the energy equation of DP that is incorrect, as is obvious from the fact that the left-hand and right-hand sides of the equation are dimensionally incompatible. The equation used by PKS is well known and, for example, can easily be obtained from the form derived by Braginskii (1965, Equations (1.23) and (6.36)).

It is surprising that Dwivedi and Pandey do not provide numerical solutions of their dispersion relation (as was done by PKS), instead presenting plots of the damping rate versus wavenumber based on approximate analytical expressions that apply only when the damping rate is small. These valid expressions and their derivations (that appear – to our dismay – to be taken essentially verbatim from

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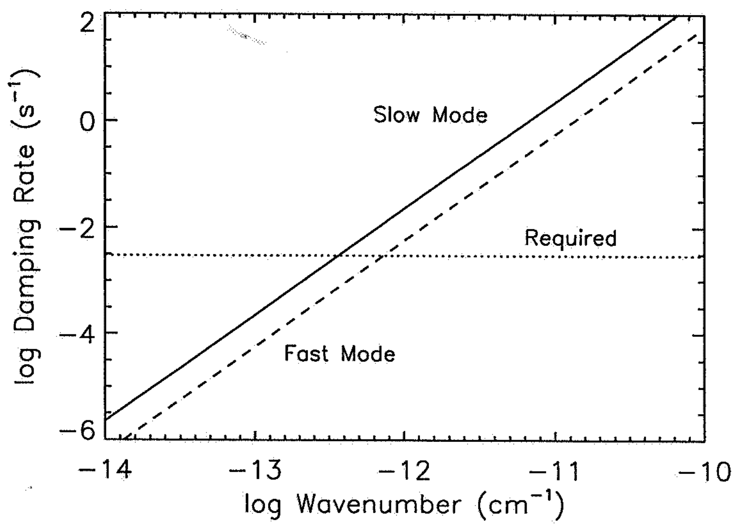

Figure 1. Damping rate versus wave number for slow mode waves (*solid*) and fast mode waves (*dashed*) assuming a compressive viscosity that is a factor of 10^8 larger than classical. The *dotted line* indicates the damping rate required to balance coronal radiation losses.

PKS Section 4 and Appendix B)* do not depend directly on the energy equation. However, the DP discussion of the critical wavenumber beyond which the thermal conduction damping expressions are invalid is based on a second erroneous form of the energy equation (Equation (38)), which is not part of the PKS derivation (Appendix C).

The damping rates shown in Figures 1–6 of DP are said to use 'modern' coefficients of compressive viscosity and thermal conduction that, curiously, are five orders of magnitude *smaller* than the classical values. The damping rates are therefore slower than classical, which is incompatible with the anomalously rapid damping measured in the oscillating loops observed by TRACE.

The TRACE loops are believed to be damped by shear viscosity (and possibly also by electrical resistivity). While there is no guarantee that a mechanism that enhances shear viscosity also enhances compressive viscosity by a comparable amount, it is interesting to consider this possibility. In Figure 1, we plot the damping rate versus wave number for slow and fast mode waves that are damped by compressive viscosity which, following Nakariakov *et al.* (1999), is taken to be 10^8 times larger than the classical value. These rates (which vary as the square of the wavenumber) are obtained from Equations (4.1.1c) and (4.2.1b) of PKS, which

*Note from the editors: Dwivedi and Pandey have copied in their paper large portion of the PKS paper without proper reference. We do not condone such unethical violations of the policy of this journal, that papers published here contain original work with appropriate references to earlier research. We apologize for failing to detect the violation when the Dwivedi and Pandey paper was being refereed. Dwivedi and Pandey were invited to prepare an apology but did not prepare one satisfactory to the injured parties.

apply when $\beta \ll 1$. We have assumed the same background coronal conditions as PKS: $n_0 = 10^9$ cm^{-3}, $T_0 = 2 \times 10^6$ K, $B_0 = 10$ G, and $\theta = 45$ deg (angle of propagation relative to the magnetic field).

The horizontal line in Figure 1 indicates the damping rate required for wave heating to balance radiation losses assuming a wave amplitude of 40 km s^{-1}, as suggested by nonthermal spectral line broadening observations (see PKS). The required rate is achieved with wavenumbers greater than about 4×10^{-13} and 7×10^{-13} cm^{-1} for slow and fast mode waves, respectively. These wavenumbers correspond to frequencies of only 9×10^{-7} and 1×10^{-5} s^{-1}. We do not show results for the damping due to enhanced thermal conduction, since the resulting wave numbers required to balance radiation far exceed the critical wavenumber at which the approximate expressions break down.

One of the criticisms of coronal wave heating has been the skepticism that photospheric motions generate sufficient power at frequencies > 0.1 s^{-1}, where damping with classical viscosity is strong. However, we see that high frequencies are not necessary if the viscosity is enhanced. Only modest enhancements are required. Waves of period 300 s (where the photospheric power is greatest) will balance coronal radiation if compressive viscosity is enhanced by a factor of 7 for the slow mode, or by a factor of 900 for the fast mode. This enhancement seems quite plausible, especially given the recent results from TRACE.

References

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